VOLUME XIX NUMBER 5 WHOLE NUMBER 149

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS
J. S. PLASKETT
Director of the Dominion Astrophysical Observatory, Victoria, B.C.
SIR FREDERIC STUPART
Director of the Meteorological Service of Canada, Toronto
R. MELDRUM STEWART
Director of the Dominion Observatory, Ottawa

PUBLISHED MONTHLY
(*Ten numbers per year*)

August-September, 1925

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WHELDON & WESLEY LTD.
2-4 ARTHUR STREET, NEW OXFORD STREET, LONDON, W.C.2

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XIX, No. 5 AUGUST-SEPTEMBER, 1925 WHOLE No. 149

Articles PAGE

The Two Hundred and Fiftieth Anniversary at Greenwich *S. A. Mitchell* 137
Astronomy in Hungary - - - - - - - *C. Lassovozky* 143
Wireless Time Signals Observed at Ottawa - - - *R. M. Stewart* 145
Results from the Toronto Meteorological Observatory *W. E. W. Jackson* 150
Three Double-lined Class B Spectroscopic Binaries - *J. A. Pierce* 153

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article stitched in a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$6 50	$ 9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

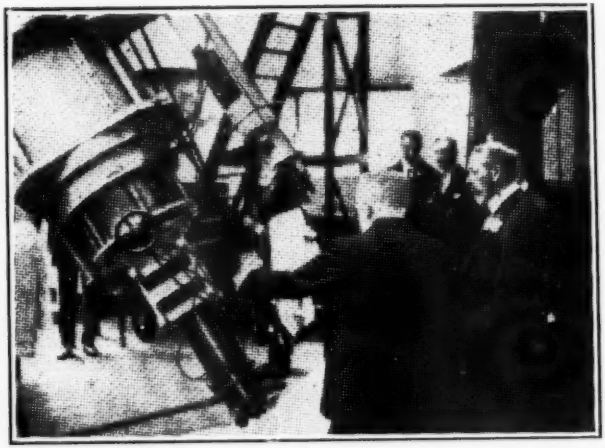
Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Business correspondence, remittances, etc., should be addressed to H. W. Barker, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.



IN THE OBSERVATORY

His Majesty listening to an explanation of the working of the great equatorial telescope at Greenwich

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. XIX AUGUST-SEPTEMBER No. 5

THE TWO HUNDRED AND FIFTIETH ANNIVERSARY AT GREENWICH

By S. A. MITCHELL

How fortunate it was that the Royal Observatory was started in 1675 so that the 250th anniversary of its foundation should occur in 1925, the year of the meeting of the International Astronomical Union in Cambridge. We astronomers from overseas had been greatly thrilled by our nine days of meetings in this old university town, the place of all places in the world for a scientific congress. The quiet dignity of the old colleges, the thrill of being in an atmosphere hallowed by the presence of Isaac Newton, John Couch Adams, Clerk Maxwell and William Wordsworth and the care with which the committee under the guidance of Professor Newall looked after our comfort made the Cambridge meeting one never to be forgotten.

The celebration at Greenwich followed immediately after the meetings at Cambridge which lasted from July 14 to July 22. The chief functions were three: an inspection by King George and Queen Mary of the Royal Observatory on the afternoon of Thursday, July 23, a conversazione by the Royal Society at their rooms in Burlington House the same evening and a luncheon at the Savoy Hotel presided over by the First Lord of the Admiralty on the following day.

On the occasion of the visit to Greenwich, the main avenue in the park through which their Majesties' motor car passed was lined

with boys from the Royal Hospital School, under the command of Captain Oliphant, R.N. The First Lord of the Admiralty, Mr. Bridgeman, shared with the Astronomer-Royal and Lady Dyson and the Mayor of Greenwich the honour of receiving the King and Queen and conducting them over the building. As the grounds of the observatory are rather restricted, the list of those honoured by invitations to the celebration has to be limited and consisted of the delegates to the International Astronomical Union with their wives, certain members of the Admiralty and some of the distinguished men of science in Britain like Sir Joseph Thomson, the Master of Trinity. Though the crowd inside was small the crowd outside was very large; in fact, on our way to the Observatory we witnessed the crowds quietly gathering on the streets ready to give a cheer as their Majesties passed.

The hour for their arrival at Greenwich was set for 3.30 p.m. A few minutes before this time we could hear the cheer passed along the street and gradually becoming louder as the ever-popular sovereigns drew nearer.

On passing inside the Observatory gates the King and Queen were conducted to the famous Octagon Room with its wide view over London and the Thames. This room of great historical interest had been made still more beautiful with flowers. Here Sir Charles Sherrington, the President of the Royal Society presented to their Majesties the following members of the Board of Visitors of the Ovservatory: Dr. J. H. Jeans, Sir William Bragg, Professor A. Fowler, Sir Joseph Larmor, Sir Arthur Schuster, Sir Napier Shaw, Dr. J. W. L. Glaisher, Mr. E. B. Knobel, Sir Gerald Lenox-Conyng-ham, Professor H. F. Newall, Mr. J. H. Reynolds, Colonel F. J. M. Stratton, Professor H. H. Turner, Professor A. S. Eddington, Captain H. P. Douglas and Mr. W. E. Llewellyn.

The Astronomer-Royal then presented the president and vice-presidents of the International Astronomical Union as follows: M. Baillaud (director of the Paris Observatory), W. W. Campbell (Lick Observatory and president of the University of California), de Sitter (Holland), Deslandres (France) and Cerulli (Italy). Four British astronomers were also presented: Professor R. A. Sampson (Astronomer-Royal for Scotland), Dr. H. Spencer Jones (H. M. Astronomer at the Cape of Good Hope), Dr. J. S. Plaskett

(Dominion Astrophysical Observatory) and Dr. A. W. Roberts (South Africa and member of the South African Senate).

From the Octagon Room the King and Queen went into the Clock Room, where are kept the standard clocks, and from there to the Transit Circle where with the 11-foot telescope they saw the Greenwich meridian, the imaginary line from which all of the longitudes of the world are measured. The telescopes were seen and their operations explained.

We ourselves had decided to stay near the gates of the Observatory to witness the arrival. Fortunately for us, Mr. Davidson thought we would have a much better view if we went into the newer part of the Observatory where we could witness the approach through the double line of naval Cadets. On coming into this building Mr. Newton was good enough to suggest to us that after their Majesties' arrival we might care to go into his own office. It was not expected that the King and Queen would visit this room, but from the windows we could get a splendid view of them as they approached the building. All turned out as Mr. Newton expected except in one particular. Their Majesties passed through the hall of this building and up into the dome where they inspected the photographic equatorial. We had a very excellent glimpse of the party as they ascended. On coming down they hesitated at the door of the room where a few of us were gathered, and the Astronomer-Royal explained to her Majesty that solar photographs and records were kept there. Queen Mary said she would like to see them—and her wish was law. The King took a very great interest in all that he saw, and he so surprised and thrilled one of the lady members of the staff by asking her some questions that it was some little time after the departure of the royal party that she came back to earth and gained composure. While in the room with us (about ten minutes) the King was very affable, and on leaving the room I heard him tell Mr. Bridgeman that as First Lord of the Admiralty he really ought to know a little astronomy.

The Royal Observatory has not been visited before by royalty since the reign of George III.

Among the interesting astronomical exhibits which we saw in the rooms of the Royal Society were: an Egyptian waterclock from Karnak (about 1400 B.C.); an Egyptian shadow clock, such

as was in use from very early times for indicating the passage of the hours from sunrise to noon, and then by reversing its position, from noon to sunset (about 800 B.C.); a replica of the early Egyptian measuring instrument, the "Merket" (about 700 B.C.); the original reflecting telescope of Sir Isaac Newton, made with his own hands in 1671; four object glasses of Huyghens, one with a focal length of 210 feet; and also instruments and apparatus by Sir William Herschel and Sir John Herschel.

The account of the luncheon given by the government to celebrate the 250th anniversary is taken from *The Times*. The luncheon at the Savoy Hotel was presided over by Mr. Bridgeman, First Lord of the Admiralty.

THE ADVANCE OF ASTRONOMY

Royal Observatory Anniversary

Record of 250 Years

To celebrate the 250th anniversary of the foundation of the Royal Observatory at Greenwich a luncheon was given by the Government at the Savoy Hotel yesterday. Mr. Bridgeman, First Lord of the Admiralty, presided.

In giving the toast of the Royal Observatory, the Chairman said that in 1886 two young and innocent men appeared before the examiners of Trinity College, Cambridge, in competition for scholarships at that college. One was a modern-sider and the other a classical-sider. The present Astronomer-Royal was one of the modern scientific competitors, and was, of course, successful, while he (Mr. Bridgeman) was one of the classical competitors, and was successful too. (Cheers.) He had only to draw a parallel between their careers. From that moment the Astronomer-Royal began to mount *sic itur ad astra*, and he (the speaker) began to descend. (Laughter.) He descended until that morning, which he had spent in investigating the bowels of the earth in company with the mineowners and miners, who, as might possibly be known, were not quite agreed on matters at the moment. (Laughter.) He could only hope it would not put off other classical aspirants from trying again to get honours in classics, because of a feeling that all the jam went to the scientific side. (Laughter.) He ought to congratulate the Astronomer-Royal on some of his latest triumphs, in particular in securing the gold medal of the Royal Astronomical Society. For his own part he might get a chunk of coal at his

head. (Laughter.) Continuing, Mr. Bridgeman said that he was not sure that the toast ought not to be to the pious memory of Charles II., who never got the credit which was his due. It was entirely owing to his intelligence and energy that the Greenwich Observatory was founded. The Navy owed him a great deal. He was an admirer of the Navy (although in his reign we were not so successful as we were now), and asked for money for cruisers and other up-to-date vessels of the time. (Laughter.) But in those days the people were not quite sure that the money, if provided, would be spent altogether in the way they desired. (Laughter.) Charles II. was the great benefactor who started that institution. People should put it to his credit and stand up for him against some of those who were inclined to condemn him for other characteristics he possessed. (Laughter.)

The work of the Observatory was to keep time in its proper place. The ordinary individual citizen was apt to say with Shakespeare that "times are out of joint, oh! cursed spite, that ever I was born to set it right." The Astronomer-Royal said "times are out of joint, are they? I will put it right in a minute" (laughter)—and he did. They in the Navy were very grateful to him for keeping their chronometers correct and enabling them to be as punctual as any other Service of his Majesty. The odd thing was that Father Time did not seem to mind being ordered about by Greenwich Observatory. He was told that in 250 years there had only been nine Astronomers-Royal. Compare that with the Admiralty, and it would be found that there had been 14 First Lords in the last 15 or 20 years. From that he deduced that time liked being kept in its place, and the reason was that Greenwich Observatory was managed by such admirable men as his friend the Astronomer-Royal. (Cheers.) He coupled with the toast the name of Sir Charles Sherrington, President of the Royal Society, which was also founded by Charles II.

Sir Charles Sherrington said that the anniversary was of interest not only to the Observatory, but to science generally. Owing to its conspicuous achievements and its splendid record of service to science, the Royal Observatory was a source of inspiration for the present and the future. The Royal Society cherished no connexion more than its tie with the Observatory. Referring to the association of the Observatory with the Navy, Sir Charles Sherrington said that Pepys, the Secretary of the Admiralty, was

President of the Royal Society. It was a pity that the Diary concluded just before the Observatory was founded, owing to Pepys's failing sight. Had he gone on what a revealing document would have been left for posterity! The science which was the basis of the art of navigation would remain one of the chief duties of Greenwich. We were a maritime nation, and therefore the work at the Observatory was of the deepest interest to us. He felt sure it would continue to take its share in bringing to the utmost perfection that national art.

Sir Frank Dyson, the Astronomer-Royal, in proposing "Our Guests," said that the oldest existing observatory in Europe was at the Vatican. It was founded by Pope Gregory XIII., who instituted the Gregorian calendar. After that came Leyden in 1632, Copenhagen in 1637, Paris in 1667, and Greenwich in 1675. There was then a gap. In the latter half of the 18th century came Prague, Geneva, Milan, Oxford, Rome, San Fernando, Madrid, and Coimbra. In 1820 two observatories in which England had particular interest were brought into being—Cambridge and the Cape of Good Hope. They were the only observatories which had passed their century. Later came the American observatories, which sprang up with surprising rapidity, and commenced in 1840 with Harvard and Philadelphia, followed by many others, which had contributed so largely to the progress of astronomy. Victoria, in Canada, was opened in 1917. The last observatory of all, due to the enthusiasm of Professor Schlesinger, and the public spirit of Yale University, was started only this year at Johannesburg, and was opened by the Prince of Wales hardly six weeks ago. All rejoiced at their success. Fortunately, astronomy was a subject in which no material interests were involved, and so their competition with one another was entirely of a friendly character. All liked to do things before the other, but each rejoiced at the other's success. (Cheers.)

Professor B. Baillaud, who replied, referred to the wonderful position occupied by Greenwich from the standpoint of the whole world.

Professor W. W. Campbell (of Lick and California), who also responded, said that Greenwich had never been more active than in the present decade. It was thoroughly wide awake. Its influence in the world had never been greater.

Professor H. H. Turner also replied.

ASTRONOMY IN HUNGARY

By C. Lassovszky*

THREE observatories, the University in Budapest, and a newly-formed amateur society cultivate the science of astronomy at present in Hungary. At the university four professors (Harkanyi, Kövesligethy, Terkan and Wodetzky) lecture on astronomy, and the department has a well equipped Student's Observatory.

The other two observatories are the Hungarian National, and the Haynald Observatory. The latter is a Jesuit institution and is known especially by Father Fenyi's sun observations. The National Observatory was established by an enthusiastic Hungarian magnate N. Konkoly in 1871, operating first as a private observatory in Ogyalla. Later, in 1899, he presented it to the Hungarian State on the express condition that the State preserve it for the development of astronomy in Hungary. It was planned during his life to move the observatory to another site where the meteorological conditions were more favourable, but the execution of this plan was postponed on account of the outbreak of the war. After the war, Ogyalla passed into the possession of Czechoslovakia, and if the chief instruments of this Hungarian foundation had not been transported to Budapest before the occupation it would have been impossible for the Hungarian government to fulfil the stipulations of the founder.

On account of the unfortunate economical conditions, it is a difficult task for the government to build a new shelter for the fled observatory. Yet, the dome for the 8-in refractor and the transit house are already completed, and the principal building containing the offices, library, laboratory and the mechanical workshop is nearing completion. The city of Budapest gave a suitable site for the observatory in the vicinity of the metropolis, on a mount approximately 1,600 feet high, conducting there also, light and

*Dr. C. Lassovszky of the Hungarian National Observatory in Budapest is on a one year tour of inspection of the observatories in the United States and Canada.

water. The Municipal Council decided to build the dome for the double telescope (24-in. reflector and 12-in. refractor) which is being made by the Carl Zeiss and G. Heyde firms.

The Konkoly Observatory executed chiefly photometric observations. In 1916 the photometric catalogue covering the zone 0° to −10°, is a continuation of the Potsdamer Durchmusterung. The reductions for the zone −10° to −15° are now being made and will soon be ready for publication. The volume containing the variable star observations is now in the press. Latitude variation observations with the transit instrument began a year ago.

In the rebuilding of the institution particular merit is due to the director A. Tass, who awakened the greatest interest not only among official but many other circles. Several banks donated sums of money and many manufacturers supplied building materials and helped with the interior fittings. The Observatory is very grateful to the foreign observatories and societies who sent their publications and in some cases duplicates to replace the loss of the library.

Last year the Stelle Astronomical Society was formed to maintain the public interest in astronomy and the observatory. For this purpose lectures are given to the members and it is expected to publish a journal and an annual almanac. Already since May 1924 there are more than 1,100 members. In addition to the astronomical ephemerides for amateur observers the first volume of the almanac (1925) contained thirteen articles on astronomy and related sciences. One part of the book contains an account of the activities of the society. The demand for the almanac was so great that a second edition was necessary.

We hope that Hungary, in spite of the severe conditions and the great misfortune due to the loss of the observatory in Ogyalla, will take its place beside the other nations in the astronomical world.

Victoria, B.C.,
June 30, 1925.

WIRELESS SIGNALS OBSERVED AT OTTAWA

By MELDRUM STEWART

BULLETIN No. 8

Date 1924	Ottawa-Washington				Lafayette (G. Sid. T.)		ΔT at 10 p.m.	
	Observed		Corrected					
	Noon	10 p.m.	Noon	10 p.m.	1st beat	300th beat	Obsd.	Adopted
	s	s	s	s	h m s	h m s	s	s
July 1	+.11	+.17	+.01	+.05	14 44 53.66	14 49 46.91		− 3.193
2	+.12	+.14	+.02	+.02	48 38.63	53 31.88	− 3.436	− 3.422
3	+.07	+.07	+.02	+.02	54 23.40	59 16.68	− 3.626	− 3.628
4	+.06	+.06	+.01	+.02	55 13.97	15 0 7.22	− 3.839	− 3.848
5	+.06		+.03		15 2 56.40	7 49.67	− 4.109	− 4.125
6	+.04	+.04	+.02	+.02	8 40.44	13 33.70		− 4.380
7	+.01	+.01	.00	.00	14 24.70	19 17.97		− 4.640
8	+.01	−.03	+.01	−.02	12 17.80	17 11.07		− 4.922
9	+.02	+.05	−.03	−.01	19 0.73	23 53.99		− 5.292
10	+.04	+.05	−.03	−.02	20 49.73	25 42.99	− 5.691	− 5.677
11	+.09	+.09	−.01	.00	24 36.20	29 29.46	− 5.990	− 5.983
12	+.08	+.10	−.02	−.01	27 23.76	32 17.01		− 6.329
13	+.11	+.07	−.01		33 7.65	38 0.87		− 6.629
14	+.04	+.09	−.01	−.01	38 51.79	43 45.06	− 6.876	− 6.884
15	+.05		−.02		39 41.53	44 34.81		− 7.186
16	+.08	+.10	+.01	+.02	41 28.97	46 22.25		− 7.530
17	+.14	+.12	+.05	+.06	52 6.50	56 59.79	− 7.894	− 7.882
18	+.11	+.14	+.04	+.05	51 57.37	56 50.64	− 8.292	− 8.325
19	+.12	+.11	+.03	+.05	53 45.43	58 38.68	− 8.763	− 8.742
20	+.11	+.11	+.02	+.06	57 30.61	16 2 23.87	− 9.066	− 9.080
21	+.11	+.11	+.04	+.02	16 9 6.94	14 0.21	− 9.382	− 9.385
22	+.11	+.10	+.03	+.03	10 54.97	15 48.21	− 9.670	− 9.679
23	+.11	+.11	+.03	+.01	12 42.88	17 36.13	−10.017	− 9.982
24	+.10	+.11	+.03	+.02	15 30.30	20 23.58		−10.399
25	+.09	+.12	+.02	+.02	24 11.76	29 5.03	−10.871	−10.893
26	+.10	+.11	+.03					−11.450
27	+.10		+.01		34 41.64	39 34.91		−11.996
28	+.13	+.14	+.05	+.05	29 37.42	34 30.68	−12.517	−12.504
29	+.13	+.15	+.04	+.06	34 21.60	39 14.85	−12.906	−12.924
30	+.15	+.11	+.06	+.03	43 59.94	48 53.21	−13.346	−13.340
31	+.13	+.17	+.03	+.07	51 41.24	56 34.50	−13.753	−13.768
Aug. 1	+.13	+.11	+.04	+.01	16 43 41.53	16 48 34.80	−14.232	−14.204
2	+.11	+.09	+.03	+.01	49 25.37	54 18.63	−14.562	−14.579
3		+.09		+.03	54 9.93	59 3.18		−14.938
4	+.09	+.11	+.02	+.05	58 54.15	17 3 47.40		−15.288

Date 1924	Ottawa-Washington				Lafayette (G. Sid. T.)		ΔT at 10 p.m.	
	Observed		Corrected					
	Noon	10 p.m.	Noon	10 p.m.	1st beat	300th beat	Obsd.	Adopted
	s	s	s	s	h m s	h m s	s	s
Aug. 5	+.10	+.09	+.02	+.03	16 59 42.52	4 35.77	−15.680	−15.682
6	+.12		+.05		17 10 18.68	15 11.95		−16.072
7		+1.11		+.04			−16.523	−16.529
8		+.09		+.02				−16.991
9	+.06	+.05	−.01	.00			−17.457	−17.437
10	+.02	+.02	−.03	−.01				−17.922
11	+.10	+.12	.00	+.01	26 5.36	30 58.64	−18.418	−18.425
12	+.07	+.07	−.02	.00	38 40.21	43 33.43		−19.009
13		+.10		+.01	46 21.14	51 14.39		−19.644
14	+.06	+.09	−.03	+.01	44 13.35	49 6.61	−20.247	−20.230
15	+.07	+.08	.00	+.02			−20.751	−20.750
16	+.11	+.12	.00	+.01	45 48.93	50 42.22		−21.289
17	+.14	+.16	+.03	+.04	59 22.24	18 4 15.50		−21.795
18	+.10	+.08	+.05		51 21.16	17 56 14.41	−23.216	−23.227
19	+.06	+.09	+.01	+.04	59 1.66	18 3 54.93		−23.243
20	+.05	+.08	+.01	+.05	18 2 47.05	7 40.32	−23.269	−23.266
21	+.03	+.05	+.01	+.04	8 30.10	13 23.37	−23.274	−23.296
22	+.06	+.04	−.02	−.03	11 16.48	16 9.74		−23.335
23	+.02	−.01	−.05	−.02	15 1.28	19 54.55	−23.395	−23.372
24	−.04	−.05	−.05	−.06	14 51.36	19 44.61		−23.397
25	+.02	+.04	−.07	−.06	19 35.71	24 28.97		−23.409
26	+.05	+.04	−.03	−.04	23 20.79	28 14.05	−23.418	−23.414
27	+.01	+.04		.00			−23.412	−23.417
28	+.04	+.02	.00	+.02	45 34.52	50 27.79	−23.424	−23.439
29	+.10	+.09	+.02		42 27.82	47 21.08		−23.480
30	+.06	+.06	−.02		43 16.13	48 9.38		−23.519
31	+.03	+.07		+.02				−23.571
Sept. 1	+.03	+.01	−.02	−.03				−23.619
2	−.02	−.02	−.04	−.06	18 55 30.36	19 0 23.61	−23.671	−23.655
3	−.03	−.04	−.01	−.02	59 15.25	4 8.50		−23.670
4	−.05	−.01	−.02	+.01	19 6 55.90	11 49.17	−23.681	−23.689
5	+.02	+.06	−.02	+.01	7 44.13	12 37.38		−23.710
6	+.04	+.10	−.03	+.03				−23.735
7	+.06	+.06	−.01	+.01	17 12.08	22 5.33		−23.752
8	+.03		−.01		20 57.38	25 50.63		−23.775
9	+.08	+.09	−.01	+.03	24 42.33	29 35.58		−23.804
10	+.03	+.08	−.04	+.01	27 28.82	32 22.07		−23.833
11	+.08	+.06	+.03	+.03	31 13.89	36 7.14	−23.858	−23.873
12	+.04	+.03	+.03	+.05	35 57.77	40 51.03		−23.919

Date 1924	Ottawa-Washington				Lafayette (G. Sid. T.)		ΔT at 10 p.m.	
	Observed		Corrected					
	Noon	10 p.m.	Noon	10 p.m.	1st beat	300th beat	Obsd.	Adopted
	s	s	s	s	h m s	h m s	s	s
Sept. 13	+.05	+.06	+.01		19 36 46.75	19 41 40.01		−23.975
14	+.04	+.03		+.01	41 32.30	46 25.56		−24.026
15	+.03	+.03	.00	.00	54 8.28	59 1.55		−24.073
16	−.03	+.04	−.07	.00	51 1.00	55 54.25		−24.121
17	.00	+.02	−.04	.00	52 47.12	57 40.38		−24.178
18	+.06	+.07	−.01	−.02	57 30.62	20 2 23.87	−24.241	−24.231
19	+.03	+.09	−.05	+.01	20 0 17.09	5 10.34	−24.314	−24.314
20	+.09	+.10	.00		4 1.16	8 54.41		−24.344
21	+.10	+.10	−.04	−.02				−24.368
22	+.10	+.11	−.02	−.01	11 29.37	16 22.62		−24.383
23	+.11	+.13	−.03		15 12.96	20 6.21	−24.410	−24.395
24	+.06	+.08		.00	21 51.48	26 44.73	−24.380	−24.398
25	+.08	+.05	+.02	+.01	25 33.62	30 26.87	−24.412	−24.414
26	−.01	+.05	−.03	+.04	28 17.94	33 11.19	−24.426	−24.451
27	+.03		+.01		35 56.71	40 49.96	−24.515	−24.505
28	.00	+.02	.00	+.03	47 30.57	52 23.82		−24.540
29	−.01	−.02	+.01	+.01	42 23.19	47 16.45		−24.589
30	−.06	−.07	+.01	.00	44 8.25	49 1.50		−24.626
Oct. 1	+.09	+.09	+.02	+.03	20 49 47.74	20 54 40.99	−24.654	−24.653
2	+.10	+.11	−.01	−.01	54 28.70	59 21.95	−24.707	−24.699
3	−.01	+.07	−.01	.00	59 9.62	21 4 2.87	−24.739	−24.732
4	+.07	+.07	−.04	−.03	58 56.67	3 49.93		−24.758
5	+.06	+.08	−.05	−.04	21 3 38.14	8 31.40		−24.760
6	+.02	+.01	−.04	−.02	8 19.20	13 12.45		−24.767
7	−.01	.00	−.04	−.04	36 5.75	40 59.23		−24.785
8	−.02	−.03	−.06	−.06	19 4.93	23 58.31	−24.790	−24.808
9	−.05	−.04	−.07	−.04	19 24.64	24 17.86	−24.862	−24.819
10	−.02	−.05	−.04	−.06	25 5.79	29 59.04	−24.804	−24.812
11	−.02	+.01	−.05	−.03	36 39.01	41 32.26		−24.804
12	.00	.00		.00	29 33.98	34 27 23		−24.796
13	−.01		.00		37 11.57	42 4.82		−24.799
14	−.02	.00	+.01	+.02	41 53.15	46 46.40	−24.786	−24.806
15	−.06	−.07	−.01		45 36.68	50 29.93	−24.861	−24.818
16	−.07	−.06	.00	+.01	45 23.35	50 16.60	−24.803	−24.828
17	+.05	+.04	.00	.00	51 2.03	55 55.29	−24.835	−24.834
18	+.03		−.02		52 44.88	57 38.13		−24.828
19	+.05	+.07	−.01	+.01	56 25.58	22 1 18.83		−24.828
20	+.03	+.07	−.01	−.01	22 1 5.16	5 58.41		−24.829
21	+.08	+.08	−.02	.00	6 44.15	11 37.40		−24.831
22	+.06	+.08	−.02	.00	12 23.30	17.16.56	−24.830	−24.841

Date 1924	Ottawa-Washington Observed Noon	Observed 10 p.m.	Corrected Noon	Corrected 10 p.m.	Lafayette (G. Sid. T.) 1st beat	300th beat	ΔT at 10 p.m. Obsd.	Adopted
	s	s	s	s	h m s	h m s	s	s
Oct. 23	+.08	+.08	−.01	−.01	22 16 4.84	22 20 58.09		−24.855
24		+.08		−.03	17 48.21	22 41.47	−24.891	−24.876
25	+.05	+.05	−.01		23 26.78	28 20.03	−24.869	−24.885
26	+.05	+.03	.00	−.01	29 8.02	34 1.27		−24.887
27	+.03	+.03	−.02	−.03	30 55.75	35 49.00	−24.909	−24.897
28	+.02	+.03	−.03		39 35.06	44 28.31	−24.886	−24.908
29	.00	.00	−.03	−.03	38 24.25	43 17.50	−24.942	−24.920
30	+.05	−.05	−.03	−.03	43 6.46	47 59.71	−24.921	−24.923
31	+.04	+.04	−.06	−.04	46 49.02	51 42.27		−24.924
Nov. 1	+.02	−.02	−.06	−.07	22 50 31.69	22 55 24.94		−24.943
2	+.02	+.01	−.04	−.06	54 14.42	59 7.67		−24.954
3	+.03	+.02	−.06	−.06	23 21 30.40	23 26 23.65		−24.951
4	−.01	+.02	−.07	−.06	2 39.84	7 33.10		−24.958
5	+.01	+.02	−.06	−.06	11 16.71	16 9.96		−24.964
6	+.01	+.02	−.06	−.04	19 53.11	24 46.36		−24.965
7	+.01	+.01	−.07	−.05	11 49.55	16 42.80		−24.973
8	+.01	.00	−.04	−.02	25 21.01	30 14.27	−24.969	−24.968
9	−.03	−.02	−.06	−.04	24 8.97	29 2.22		−24.967
10	+.02	−.01	.00	.00	24 55.02	29 48.27		−24.960
11	+.01	+.02	−.01	+.01	42 21.29	47 14.54		−24.955
12	+.10	+.08	+.02		43 8.04	48 1.29	−24.959	−24.960
13	+.10		−.02		36 3.65	40 56.90		−24.968
14	+.11	+.10	−.01	−.03	41 44.93	46 38.19		−24.979
15	+.09	+.05	−.03		51 22.37	56 15.62		−24.986
16	+.03	+.04		−.02	48 13.97	53 7.22		−24.969
17	+.02	+.03	−.05	−.05	53 55.77	58 49.02	−24.994	−24.988
18	+.08	+.11		−.03	57 38.83	0 2 32.08		−24.975
19					0 4 18.34	9 11.59		−24.958
20	+.02	+.04	−.05	−.03	5 5.69	9 58.94		−24.939
21	+.07	−.08	−.03	−.01	7 50.41	12 43.67		−24.927
22	+.08	+.08	+.01		12 34.06	17 27.31		−24.906
23	+.06	+.06	−.01	−.01	18 14.29	23 7.53		−24.890
24	+.05	+.04	−.02	−.04	26 50.70	31 43.95		−24.861
25	+.03	+.02	−.04	−.04	29 34.38	34 27.63		−24.841
26	+.05	+.06	−.03	−.05	28 20.85	33 14.11		−24.811
27	+.09	+.09	−.02	−.04	32 2.34	36 55.59	−24.790	−24.779
28	+.10	+.09	−.04	−.02	35 44.45	40 37.70	−24.740	−24.741
29	+.07	+.04	−.03	.00	39 26.18	44 19.43		−24.698
30	+.04	+.05	+.01	+.01	43 7.53	48 0.78		−24.650

Date 1924	Ottawa-Washington				Lafayette (G. Sid. T.)		ΔT at 10 p.m.	
	Observed		Corrected					
	Noon	10 p.m.	Noon	10 p.m.	1st beat	300th beat	Obsd.	Adopted
Dec. 1	+.05	+.04	.00	−.01	0 48 46.59	0 53 39.84		−24.606
2	+.07	+.05	−.01	.00	50 30.75	55 24.00		−24.560
3	+.06	+.04	+.01		1 11 52.21	1 16 45.47		−24.520
4	+.04	+.05	+.01	+.03	0 58 53.42	3 46.67	−24.469	−24.481
5	+.05	+.06	+.03	+.04	1 4 33.50	9 26.75		−24.453
6	.00	.00	+.03	+.02	8 16.84	13 10.09		−24.429
7	−.11		−.03		12 59.27	17 52.52		−24.413
8	−.09	−.10	−.01	−.01	18 39.07	23 32.32		−24.394
9	−.07		.00		22 21.24	27 14.49		−24.377
10	+.08	+.09	+.01	.00	24 5.64	28 58.89		−24.352
11	+.09	+.08	−.02	−.02	27 46.82	32 40.08		−24.329
12	+.08	+.09	−.02	−.01	38 20.03	43 13.28		−24.297
13	+.12	+.10	+.01		36 8.07	41 1.32		−24.271
14	+.11	+.09			38 50.20	43 43.45		−24.239
15	+.07	+.11	−.03	−.01	43 30.19	48 23.44		−24.215
16	+.10		−.03		47 10.73	52 3.98		−24.184
17	+.10	+.09	+.02		49 52.22	54 45.47		−24.146
18	+.06	+.05	+.04	+.04	54 32.13	59 25.38		−24.116
19	+.12	+.11	+.04	+.04	2 0 11.12	2 5 4.37		−24.081
20	+.07	+.08	+.04		14 41.88	19 35.13	−24.046	−24.047
21	+.09	+.07	+.07	+.06	17 25.08	22 18.33		−24.020
22	+.09	+.14	+.05	+.06	16 13.00	21 6.26		−23.982
23	+.09	+.11	+.03	+.05	17 56.71	22 49.96		−23.954
24	+.08	+.11	+.02	+.05	19 40.51	24 33.77		−23.922
25		+.09		+.05	24 20.56	29 13.82		−23.885
26	+.09	+.11	+.02	+.03				−23.858
27		+.06		+.02	30 45.40	35 38.66		−23.822
28					34 26.60	39 19.86		−23.786
29	+.10	+.10	+.02	+.03				−23.742
30	+.07	+.06	+.03	+.04				−23.721
31					47 29.05	52 22.29		−23.678

RESULTS FROM TORONTO METEOROLOGICAL OBSERVATORY

The accompanying table of sunspot numbers gives the results of the observations of sunspots made at the Toronto Observatory during the year 1924. They were obtained by visual count of the spots and groups using the 6 inch Cook refractor and magnification of 60 diameters, and by use of the Wolfer formulae $10g+S=N$. Where g is the number of groups, S the number of spots and N the resultant sunspot number. A marked increase in the frequency that spots were visible was apparent as the year advanced.

The following table of the Ranges in Magnetic Declination at Agincourt for each day of the year exhibits some striking contrasts to the sunspot numbers. For example on January 29 no spots were visible, whilst the greatest range in Declination for the year was observed. During the last few days of February a small group of spots was observed whilst the magnetic range was at its minimum. During May and June an increase in sunspots occurred at the same time as an increase in Declination range. A large increase in sunspots during the second and third weeks of November, however, occurred when there was very little evidence of activity in the magnetic state of the earth; only on two days of this period, the 19th and 24th, was there observed any marked increase in the range of Declination.

SUNSPOT NUMBERS FROM OBSERVATIONS MADE AT TORONTO OBSERVATORY DURING 1924

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
1			15							43	13	0
2				0	0		32	25	48	44		
3			12		0		31		58	52	0	
4				0			34		53	38	0	12
5	0			0	0		41	23	37		0	
6						43		22	25	47	0	
7			0	0	22	41		22			11	
8		0		0			36	22	11	34	0	
9	0						49			51		
10				0	22	21	46		20	30		
11		0		0			46		22	23	29	
12							42	11	24		11	
13		0	0		34	44			27	23		
14	0			0		47		0		26	15	
15		0	0		38		29		20	18	34	
16		0			76	31			18	25		
17	0		0		50	30	12		15	17		
18		0	0			15		13	13		32	
19			0	42			0		13		53	
20			0		34	17				16	34	16
21		0			29	15		11	29	19		
22					29		0			18		
23	0	0		26	27	13	0	13	24	20		
24	0		0	26		11			27	17		17
25	0			19		11		13	30	42		
26		21			11	11	0	12	15		47	0
27		20	0			25		0	25			
28		18	0	0	25	13		26		29		
29	0	18		0	10		15	58		31	14	
30			0		20	14		51		29		
31					16							0
Mean	00	6	2	8	25	24	26	20	26	29	18	8

DAILY RANGE IN MAGNETIC DECLINATION AT AGINCOURT DURING 1924

	′	′	′	′	′	′	′	′	′			
1	6	12	5	12	13	17	15	22	35	13	14	7
2	5	6	11	11	10	16	20	17	18	13	14	11
3	20	10	19	14	14	12	14	14	16	13	12	7
4	14	8	9	12	15	15	17	15	17	16	9	5
5	5	22	15	10	16	20	15	18	16	8	9	5
6	9	18	16	14	12	12	20	20	15	10	9	3
7	7	12	30	18	13	14	13	11	45	14	10	15
8	7	10	19	9	15	13	15	7	29	12	7	10
9	5	8	19	13	10	17	18	11	18	8	12	6
10	33	18	19	7	8	48	18	15	16	9	11	6
11	10	10	11	10	10	23	15	15	13	9	9	13
12	7	11	10	7	12	18	16	14	17	11	13	15
13	7	4	6	10	10	11	12	18	15	12	13	8
14	7	4	7	12	9	10	14	20	13	12	9	8
15	13	5	9	10	13	18	16	14	12	12	11	10
16	13	8	5	11	17	17	20	18	14	14	10	8
17	8	7	10	11	15	16	17	38	10	12	10	9
18	7	5	13	13	16	26	18	16	12	15	7	8
19	9	6	25	15	15	41	12	17	10	8	19	9
20	5	19	13	14	18	14	20	15	10	15	7	26
21	13	19	19	16	48	21	22	16	8	13	8	12
22	32	17	14	15	72	24	13	18	10	9	8	7
23	34	11	15	11	29	16	9	15	76	41	8	11
24	21	12	14	19	14	13	14	13	12	40	24	7
25	9	16	13	15	15	12	16	15	10	18	06	6
26	12	12	14	25	13	14	21	13	23	11	6	8
27	7	8	9	13	27	14	23	16	15	14	8	9
28	11	8	12	8	32	17	17	16	13	9	9	6
29	113	6	16	9	11	20	13	22	14	11	11	8
30	16		26	11	18	18	14	20	12	12	8	9
31	11		13		13		15	15		12		10
Mean	16	11	14	13	18	18	16	17	18	14	10	9

THREE DOUBLE-LINED CLASS B SPECTROSCOPIC BINARY SYSTEMS

By J. A. Pearce

Introduction

In accordance with the principles of celestial mechanics the two components of a binary system revolve in a common plane about their centre of gravity, in the same time and describe similar ellipses. The centre of gravity moves in a straight line with a constant velocity, which is readily determined from the spectroscopic observations, being designated by *Vo*, or by the greek letter γ. Ordinarily, only the brighter star records on the photographic plate, so that the observations of velocity when plotted against the time give rise to one velocity curve, generally resembling a distorted sine curve, which may be solved by one of several methods and the elements of the orbit found. When the two components differ little in mass, when $\frac{m_1}{m_2} \lesseqgtr 0.7$, the spectral lines of the less luminous star appear as faint companions to those of the brighter; and if their intensity, quality and separation permit their measurement, each observation furnishes the individual velocities of the two stars.

The measurement of double-lined spectra, therefore, gives rise to two velocity curves as shown in Fig. 1, having the same period P, eccentricity e, and whose ω's differ by 180° (ω is the angle defining the orientation of the ellipse). The curves are not solved separately, but the common elements are found from the combined data, the number of observations being thus virtually doubled.

Double-lined spectra provide additional information of the system, for the ratio of the semi-amplitudes of the curves is equal to the ratio of the masses, *i.e.*, $\frac{k_1}{k_2} = \frac{m_1}{m_2}$. It is, therefore, highly desirable when the secondary spectrum can be moderately well measured to find the amplitude and thus determine the ratio of

the masses, which cannot be determined from observations of the brighter star alone. The three double-lined binaries discussed in this article were discovered here, the orbits of the first two being completed by the Director, Dr. J. S. Plaskett, and that of the last star by the writer.

ζ^2 Cor. Bor.—H.D. 139892

1900 R.A. 15h 35.6m, Dec. +36°58′, vis. mag. 5.07, spectral type B8n.

The binary character of this star was discovered by W. H. Christie from a double-lined plate showing a relative separation of 220 km. The spectrum is of type B8n with broad, strong and ill-defined lines of hydrogen, together with weak diffuse lines of helium. The difficulties of measuring such nebulous lines were increased by their double character, the resulting probable errors per plate being ±11.8 km. per sec. for the brighter, and ±15.1 km. per sec. for the fainter component. The lines measured are given in Table I, the average number of lines being five and the maximum number nine.

The I-prism spectrograph with the medium-focus camera resulting in a linear dispersion of 29A per mm. at Hγ was used, although two of the plates were obtained with the short-focus camera which gives a linear dispersion of 49A per mm. at Hγ.

Thirty-two of the thirty-six plates secured were used in the determination of the orbit. Four plates were omitted, for, on account of their proximity to the crossing points, the double lines were blended and even approximate measures were impossible.

The preliminary elements determined by a trial and error method of a series of velocity curves for different eccentricities and longitudes of the line of apsides, were corrected by a least-squares solution after the method of Lehmann-Filhés. Sixty observation equations involving six unknowns were solved and corrections applied to all the elements except ω. This solution was performed by F. G. Young, an undergraduate in Mathematics at the University of Alberta, Edmonton. The resulting elements together with their probable errors are given in Table II.

The projected masses and separations of the components are

given in Table III. The masses are unusually high for a star of this type, and are certainly not exceeded by any other B8 stars with the possible exception of μ Sagittarii whose mass function is $3.63\odot$. But the spectrum of μ Sagittarii, and also of υ Sagittarii and β Lyrae with masses of the same order, can hardly be called of normal B8 type.

The absolute magnitude -3.2 was accepted, being the mean of the two methods later described. This value combined with the apparent magnitude of 5.8 gives a parallax of 0″.0016 or an approximate distance of 2,000 light years.

TABLE I—LINES MEASURED IN THE SPECTRA

ζ^2 Cor. Bor. −B8n	H.D. 25833 − B3		H.D. 216014 − B0n	
λ Atom	λ Atom	λ Atom	λ Atom	λ Atom
4922 He	4922 He	4144 He	*4922 He	4267 C+
4861 Hβ	4861 Hβ	4121 He	*4861 Hβ	*4144 He
4481 Mg+	4713 He	4102 Hδ	4713 He	*4121 He
4471 He	4481 Mg+	4026 He	4686 He+	4116 SiIV
4388 He	4471 He	4009 He	4651 C++	*4102 Hδ
4340 Hγ	4388 He	3970 Hε	4575 SiIII	4089 SiIV
4144 He	4340 Hγ	3934 Ca+(K)	4568 SiIII	4076 OII
4101 Hδ	4267 C+		4553 SiIII	*4026 He
4026 He			4481 Mg+	4009 He
3970 Hε			*4471 He	*3970 Hε
			*4388 He	3968 Ca+(H)
			*4340 Hγ	3934 Ca+(K)

*The amplitude of H.D. 216014 is exceeded only by that of V Puppis, for which $K_1+K_2=604$ km.[14]

The proper motion of this star according to Boss is 0″.0135 corresponding to a linear tangential velocity of 40 km. per sec. Combining this with the radial velocity of 30 km. per sec. gives a space velocity of 50 km. per sec.

This star is the brighter of the visual double Bu 7352, the 6th magnitude companion being distant 6″.15 in position angle 304°.3. These values of separation and position angle have remained unchanged for over 50 years according to Burnham, the stars possessing a common proper motion. The fainter star is of type B5 with moderately sharp lines and constant radial velocity, from

seven plates of −20 km. per sec. as compared with −30 km. per sec. for the brighter star. From the fixity of position, from the difference in radial velocity and from the fact that, with a parallax of 0″.0016 the minimum separation is 4,000 astronomical units, it seems unlikely that there can be any orbital connection between the visual pair.

H.D. 25833

1900 R.A. 4h 0.6m, Dec. +33° 11′, vis. mag. 6.61, spectral type B3.

The first plate of this star, obtained by the Director, showed a double-lined spectrum with a relative separation of 314 km. The spectrum is of type B3 with rather ill-defined lines, given in Table I. The maximum number of lines measured on a plate was eleven, and the average number eight. Although they are of somewhat better quality than those of ζ^2 Cor. Bor. the measures were difficult for the reasons previously given, the probable error of a single plate being ±13.3 km. per sec.

The 1-prism spectroscope with the short-focus camera giving a linear dispersion of 49A per mm. at Hγ was used, though two of the plates were taken with the medium-focus camera. Three of the twenty-seven plates secured showed the lines blended which rendered the measures uncertain and hence they were not used in the determination of the orbit.

Owing to the uncertainty of the measures of the secondary, the elements were determined from the primary alone, and after these were obtained, the amplitude of the secondary determined, the other elements being considered as fixed. The preliminary elements showed that the eccentricity was small and therefore both ω and T could not be separately defined. As a correction to the period was desired the observations were necessarily treated separately each being assigned a weight in conformity with the general quality of the plate, the number of lines measured and the inter-agreement of the measures. Schlesinger's equation of condition was employed, and a least-squares solution of the resulting twenty-four observation equations involving five unknowns was performed. The corrected elements and their probable errors are given in Table II.

Assigning the probable values of a temperature of 15.000° K,

a density of 0.1 times the sun, and a surface brightness of −3.3 magnitudes with respect to the sun, to this B3 star, we derive an absolute magnitude of −1.4. Eddington's method, hereafter described, gives −1.6. The mean value −1.5 combined with its apparent magnitude of 7.4 gives the hypothetical parallax of 0″.0016 equivalent to a distance of 600 parsecs or nearly 2,000 light years; practically identical with ζ^2 Cor. Bor.

TABLE II—ELEMENTS OF THE SYSTEMS

	ζ^2 Cor. Bor.		H.D. 25833		H.D. 216014	
P	12.58485	±0.1578 days	2.02858	±0.00118 dys.	2.28754	±0.00047 days
e	0.030	±0.0183	0.0512	±0.0102	0.086	±0.007
ω_1	90°		30°.103	±1°.00	289°.31	±4°.80
ω_2	270°		210°.103	±1°.00	109°.31	±4°.80
K_1	134.82	±3.19 km.	164.97	±1.89 km.	225.0	±2.66 km.
K_2	137.71	±3.20 km.	187.32	±6.1 km.	258.8	±3.33 km.
T	3855.681	±0.158 days	4039.335 days		4077.0010	±0.0325 days
γ	−29.61	±1.80 km/sec.	+15.84 km/sec.		−23.10	±1.70 km/sec.

P Period
e Eccentricity
ω_1 Periastron minus node, primary
ω_2 Periastron minus node, secondary
K_1 Semi-amplitude, primary
K_2 Semi-amplitude, secondary
T Time of periastron passage
γ Velocity of the system

TABLE III—DIMENSIONS OF THE SYSTEM

	ζ^2 Cor. Bor.	H.D. 25833	H.D. 216014
$a_1 \sin i$	23,310,000 km.	4,549,000 km.	7,051,000 km.
$a_2 \sin i$	23,820,000 km.	5,165,000 km.	8,111,000 km.
$m_1 \sin^3 i$	13.35⊙	4.86⊙	14.23⊙
$m_2 \sin^3 i$	13.06⊙	4.29⊙	12.37⊙

The K line of ionized calcium was measured on 18 plates of this star. The line is very weak and generally difficult of measurement. Although there is a total range of some 35 km. in the velocity with some indication of orbital effect, the latter is decidedly

uncertain; and the mean calcium velocity +10.5 km. does not differ much from the solar component of +7.1 km., nor indeed from the velocity of the system +15.8 km. Type B3 appears to be about the lower limit of temperature which will produce excitation in inter-stellar calcium, and the effect hence appears to be present in this example with a possible influence due to stellar calcium.

H.D. 216014

1900 R.A. 22h 44.2m, Dec. +64° 32′, vis. mag. 6.83, spectral type B0n.

The first plate of this star showed a double-lined spectrum of unusually wide separation, the relative velocity being approximately 400 km. The binary nature was discovered by Dr. J. S. Plaskett.

The spectrum is classified in the Henry Draper catalogue as B3 with the following remark: "The line Hβ is not seen as a dark line, and is suspected to be bright." The type, however, is really B0n. The lines measured for determining the radial velocity are given in Table I. Both components appear to have identical spectra, the asterisks in the table denoting those lines measured as double in an average plate. The single-lined plates show many oxygen lines but these are very weak and not suitable for measurement. The diffuse character of the lines is shown in the rather high probable error of an average plate ±7.34 km. The lines of calcium, however, are strong and, compared with the nebulous nature of the other lines, are narrow, admitting of accurate measurement, as is shown by the probable error of their mean velocity ±0.31 km. The suspected emission of Hβ referred to in the quotation above is not confirmed, it appeared as a good absorption line on all the plates.

Twenty-one I-prism plates were secured principally with the short-focus camera. These were measured, as were those of the two stars previously described, on a Toepfer micrometer engine, having a binocular eyepiece which is more restful on the eyes than the ordinary single-ocular machine. The secondary spectrum was measured on all but three of the plates, so that the elements of the orbit were determined from thirty-nine observations.

In the least-squares correction to the elements, the equation of condition of Lehmann-Filhés was used. A correction to the period was included, as the observations only extended over thirty-eight cycles. Weights were assigned to the measured velocities in accordance with the quality of the plate, the number of lines measured and degree of precision of the fainter measures with respect to those of the brighter component. The thirty-nine observation equations involving seven unknowns thus formed resulted in the elements given in Table I.

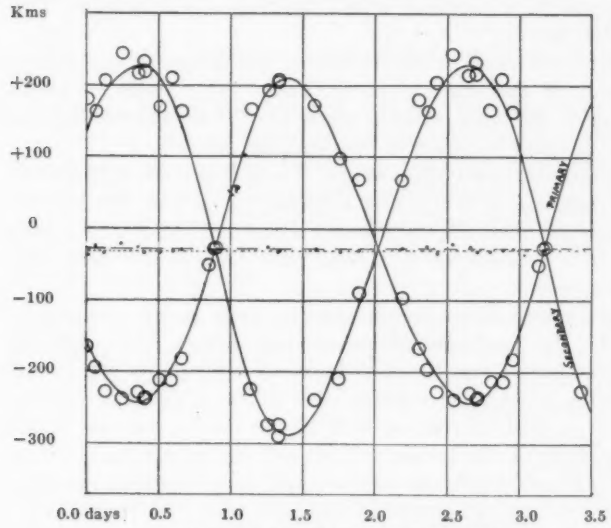


Fig. 1. Velocity Curves of H.D. 216014

In order to see whether the inclusion of the less certain measures of the fainter component materially contributed in defining the elements, or whether they produced a detrimental effect, a second solution was carried out for the brighter component only. The resulting elements differed very little from the first set, although their probable errors in all cases except that of K_1 were higher, thus showing that the inclusion of the secondary measures was justifiable, as we would expect from theory. We are here, how-

ever, dealing with diffuse lines, and not with well-defined ones, and it is questionable whether with very faint secondary lines of early type spectra the gain in accuracy compensates for the additional labour involved. Experience has led some investigators of double-lined B-type binaries to base the elements upon the measures of the primary, and the test made in the case of this star would support that contention in those cases where the quality of the lines is such as to make the measures of the secondary component untrustworthy. For a comparison of the two sets of elements and their probable errors the reader is referred to Pub. D.A.O., III, No. 6.

The elements lead to the values of the projected dimensions and masses of the stars given in Table III. These minimum masses are of the same order as those for ζ^2 Cor. Bor., being well above the average for stars of this spectral class.

Assigning the conservative values of a temperature of 20,000° K, surface brightness of -3.75 and a density of 0.08 to this B0 star, we find by two methods an absolute magnitude of -2.58 corresponding to a parallax of $0''.00095$, 1050 parsecs, or more than 3,400 light years.

The stationary nature of the calcium lines in the spectrum is important. In contradistinction to the diffuse hydrogen and helium lines, the H and K lines of ionized calcium are strong and sharp, giving a constant velocity of -26.28 ± 0.31 km. per sec. This value is close to that of -23.10 ± 1.70 km. per sec. found for the velocity of the system. If these lines are produced by an interstellar cloud of calcium vapour quite apart from the spectroscopic binary, the observations indicate that the cloud has a velocity of approach of 15 km. per sec., as the component of the solar motion in this direction is -11.40 km. only. Differences of this order and even greater, between the velocity of calcium and the component of the solar motion, do not appear to be unusual among the O- and early B-type stars, as has been shown by Dr. Plaskett,[1] Young[2] and others.

An alternative explanation is to place the calcium cloud within the star's gravitational domain, at a distance of 40 to 50 astronomical units. It would then hardly be expected to show the motions of the rotating binary, and the resulting lines would be

stationary, possessing approximately the velocity of the system. It is reasonable to suppose that the ionized calcium has been expelled from the star through ionization impact as Saha[3] has pointed out, and at this far distance settled into a state of equilibrium between the gravitational pull of the star and the outward pressure also acting radially. This alternative location for the ionized calcium does not appear to be inconsistent with the well-established hypothesis of Dr. Plaskett in regard to stationary clouds of calcium and sodium vapour.

Explanation of the methods employed

The readers of the Journal may be interested in following in greater detail the methods used in assigning values of the absolute magnitudes to the stars previously described, and thus in finding their distances which are so enormously great, that the question may well be asked, "How are these distances determined?" As an illustrative example we will take H.D. 216014 and outline the various steps involved.

The fundamental equation is the relation between the absolute and apparent magnitude of the star, *i.e.*,

$$M = m + 5 + 5 \log \pi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where M = abs. mag.
m = app. mag.
π = parallax

the unit of distance being a parallax of 0″.1, 10 parsecs or 32.6 light years. If the M can be found, the distance is readily computed by the above formula since the m is known. There are two ways of determining M: (1) By assigning probable values of the surface brightness and surface area, and thus determine the luminosity, (2) By the theoretical considerations of Eddington.

(1) *Luminosity Method*

This method is based upon the two equations:

$$M' = \frac{4}{3}\pi\rho b^3 \quad \ldots\ldots (2)$$

$$L = \pi b^2 j \quad \ldots\ldots (3)$$

where M' = mass
ρ = density
b = radius
L = luminosity
j = surface temperature

Since the sun is taken as the standard, these equations become:

$$M' = \rho b^3 \odot \quad \ldots\ldots (4)$$

$$L = b^2 j \odot \quad \ldots\ldots (5)$$

The Density

Some uncertainty exists in our estimation of the density. We know from the early class B eclipsing variables that the average density of these stars is 0.05 with a range from 0.0004 to 0.18. Also, Seares[4] in his discussion on the masses and densities of the stars, gives the density of a B0 star of mass $M' = 10\odot$, as 0.04[5] for the dwarfs, and 0.08 for the giants. Adopting $\rho = 0.08$ for the brighter component of the star under discussion, we have its volume is 178, linear diameter is 5.62 and surface area 31-6 times the sun.

The Surface Brightness

The surface brightness, j, may be computed by Hertzsprung's[5] formula based on Planck's radiation law:

$$J_H = +2.3\left(\frac{14300}{T}\right)^{0.93} + \text{constant} \quad \ldots\ldots (6)$$

For a temperature of 20,000° K, corresponding to B0, J_H is found to be -3.47 mag.

Again the surface brightness for this type of star may be found in another way. It has been found that the difference in surface brightness of two stars expressed in stellar magnitudes is proportional to the difference in their colour indices. That is, this equation holds:

$$j_2 - j_1 = K(i_2 - i_1) \quad \ldots\ldots (7)$$

The constant K is the same for all stars, but depends on the wavelength of the light used in measuring the colour indices. Russell[6] has obtained as a mean K=4.0 and he showed how the apparent diameter of a star can be determined from its surface brightness. Later, it was found from the interferometer measures of stellar diameters, made at Mt. Wilson, that a better value for K is 4.8. Hence, again adopting the sun as standard, we have:

$$\Delta j = -4.8\ (\Delta i) \quad \ldots\ldots (8)$$

$$= -4.03 \text{ mag. where } \Delta i = i_{Go} - i_{Bo} = 0.84$$

Giving equal weight to these estimates of j, we take the mean $j = -3.75$ mag. That is, a B0 star of temperature 20,000° is 3.75, mag. or 32 times more brilliant than the sun, per unit area.

The luminosity now readily follows:

$$L = (2.512)^{3.75} X (5.62)^2 \quad \ldots\ldots (9)$$

$$= [3.00008]$$

over 1,000 times as luminous as the sun, or expressed in magnitudes, 7.50. The absolute magnitude of the sun being +4.83, we have the absolute magnitude of H.D. 216014 as −2.67.

(2) *Eddington's Method*

In his articles on the radiative equilibrium of the stars, Eddington[7] developes the formula for computing the total radiation of a giant star, which is found to be directly proportional to the mass and inversely proportional to the opacity of the star. The absolute magnitude of the giant star is found by converting the total radiation into magnitudes, and may be tabulated as a function of the mass. Eddington's table[8] for masses up to thirteen times the sun, has been extended by Plaskett[9] in his memoir on the O-type stars to cover a range in from ten to eighty times the sun. Interpolating this table we have for our star a bolometric absolute magnitude of −3.98. For types F and G (temperature 6000°) the bolometric absolute magnitude deduced from the total radiation, agrees with the visual absolute magnitude, but for the earlier or later types a correction is necessary. This is given by Eddington[10] for the temperatures up to 12,000°, and for higher temperatures, may be calculated by the formula given by Seares.[11]

$$M - M_B = j + 10 \log T - \text{constant} \quad \ldots\ldots (10)$$

In this case the correction is +1.48, the resulting visual absolute magnitude being −2.50. Mean M = −2.58.

The Visual Magnitude and Distance

The apparent visual magnitude is 6.83, and it is necessary to find the magnitude of the separate components. Since the spectra are identical their temperatures will be of the same order. The difference in mass indicates a difference in magnitude of 0.10, so that the magnitude of the brighter star is found to be 7.53 from the relation

$$m_1 = m_{(1+2)} + 2.5 \log (2.5)^{m^1 - m^2} + 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Hence with M = −2.58, m = 7.53, the parallax is found by (1) to be 0″.00095, over 1050 parsecs or more than 3,400 light years.

Corrected Linear Diameter

With the adopted M = −2.58 we find a corrected value for the linear diameter, D = 5.40⊙, 4,667,000 miles, and this value is used in the subsequent computations.

The Apparent Diameter

It may be interesting to compute the apparent diameter according to Russell,[6] and find the distance at which the adopted linear diameter of 5.40⊙ or 4,667,000 miles would subtend this small angle. By the formula:

$$d = 0''.0087\ (0.631)^{m-j} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

For m − j = 11.28, we have d = 0″.000048. Hence the distance in light years would be

$$\pi_{L.Y} = \frac{206264.8 \div D}{d \times [12.770]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

$$[12.770] = 1 \text{ L.Y.}$$

$$= [3.532] > 3400 \text{ light years.}$$

Check Formulae

In order to check the computations we may use the following formulae expressing relations between the various physical constants of a star. They are given by Seares;[12] Nos. (14) and (15)

are equivalent to Russell's[6] formulae, and No. (18) is identical with No. (14).

$$\log d = 0.2\,(j-m) - 2.031 \quad \ldots\ldots (14)$$

$$\log D = 0.2\,(j-m) - \log \pi - 0.030 \quad \ldots\ldots (15)$$

$$\log D = 0.2\,(j-M) + 0.970 \quad \ldots\ldots (16)$$

$$D = \frac{107.4d}{\pi} \quad \ldots\ldots (17)$$

$$j = 5 \log d + m + 10.30 \quad \ldots\ldots (18)$$

For convenience we collect the adopted values of these constants for our star.

$m = 7.53$	By (14)	we have $d =$	$0''.00048$
$M = -2.58$	(15)	$\log D =$	0.737
$D = 5.40 \odot [0.732]$	(16)	$\log D =$	0.736
$d = 0''.000048$	(17)	$\pi =$	0.00095
$j = -3.75$	(18)	$j =$	-3.75
$\pi = 0''.00095$			

All in complete agreement.

The Inclination of the Orbital Plane

It is well to remember that the computations have been based upon the minimum value of the mass ($m \sin^3 i$) and therefore the distance deduced is the minimum value for the system. The actual dimensions of the binary cannot in general be found from spectroscopic observations, since the inclination of the orbital plane remains indeterminate. Only in the case of the eclipsing binaries where i approaches 90° and $\sin^3 i$ is taken as unity do we know the actual masses. The average inclination is taken in statistical discussions on the masses of stars of different spectral types, and it is found that the average class B star is ten times, and class O star fifty times as massive as the sun. Adopting the average inclination for H.D. 216014, for which $\sin^3 i = 0.65$,[13] the resulting masses would be 21.90 and 19.05 times the sun, which for the conditions of density, temperature and surface brightness assumed above give a parallax of $0''.00079$ or 4100 light years.

Recognizing that large amplitudes* point to large values for i,

*The amplitude of H.D. 216014 is exceeded only by that of V Puppis, for which $K_1 + K_2 = 604$ km[14].

it is interesting to assign values which would cause the brighter star to partially eclipse the fainter and find the variation in magnitude on the assumption of the star being an eclipsing variable. If the star were examined with a photometer and no change in brightness detected we could thus find a limiting value for the inclination, and hence a closer approximation to the real mass. Drawing the system to scale and using a planimeter to find the areas eclipsed we have the results given in Table IV.

For an inclination of 70° the mass of the system would be increased by 12% being 32.06⊙ and the resulting M = −2.80, corresponding to a distance of 3800 light years. Variations in magnitude of 0.15 can be readily detected with a photometer, but until the observations are made we shall accept the minimum masses.

The above considerations on the plane of the system are added merely to emphasize the fact that the distance determined from the minimum mass and the conservative estimates of the physical properties is the smallest value that the spectroscopic observations allow us to adduce, and that the farther values of 3800 to 4100 light years are not only possible but quite probable.

TABLE IV—ECLIPSE DATA

Inclination	Area of Secondary eclipsed	App. Mag. of Secondary at eclipse	Combined Magnitude
90°	100%	....	7.53
73	40	8.18	7.06
70	27	7.97	6.98
66	16	7.82	6.92
57	0	7.63	6.83

Conclusion

These three systems well exemplify the chief characteristics of this interesting class of very hot and very massive stars. In ζ^2 Cor. Bor. we have a B8 giant binary of low density, great volume and high luminosity. On the up-grade of its evolutionary course it has yet to pass through the early sub-divisions of the class and reach its maximum temperature. H.D. 216014, B0, is at

TABLE V—SUMMARY OF SYSTEMS

	Sun	ζ^2 Cor. Bor.	H.D. 25833	H.D. 216014
Spectral class	G0	B8n	B3	B0n
Temperature K	5,800°	12,000°	15,000°	20,,000°
Temperature F	10,400°	21,600°	27,000°	36,000°
Mass, brighter component	1.0	13.35	4.86	14.23
Mass, fainter component		13.06	4.29	12.37
Density, brighter component	1.0	0.015	0.10	0.08
Volume	1.0	890	49	178
Surface brightness	1.0	16	21	32
Luminosity	1.0	1580	330	1000
Absolute magnitude (mean)	+4.83	−3.2	−1.5	−2.58
Velocity in orbit, brighter star	(Earth = 18.4 M.P.S.)	217.0 M.P.S.	265.5 M.P.S.	362.1 M.P.S.
Velocity in orbit, fainter star		221.6 M.P.S.	301.5 M.P.S.	416.5 M.P.S.
Distance, parallax (minimum)	sun = 8″.80	0″.0016	0″.0016	0″.00095
Distance, miles (minimum)	93×10^6	12×10^{15}	12×10^{15}	20×10^{15}
Time by airoplane 120 M.P.H.	86.1 years	11×10^9 years	11×10^9 years	19×10^9 years
Time by light 186,400 M.P.S.	498 seconds	2000 years	2000 years	3400 years

or near the culmination of its career, its mass may have carried it into the later subdivisions of the 0's, λ4686 He+being the last of the lines characteristic of this type to vanish from the spectrum. H.D. 25833, B3, the least massive and the densest of the systems, precedes the other two, having passed through its apex and started downward on the dwarf branch of decreasing temperature. The minimum sizes and separations are contrasted with the sun and Mercury in Fig. II. On the same scale the earth is a dot 1/100 of the sun's diameter at two and one-half times the distance of Mercury. The first two systems are approximately twice as remote as the average class B star,[15] while the distance of H.D. 216014 is of the order of the average 0[16] and N-type,[17] the most distant of our ordinary stars. There seems to be no reasonable doubt that the light of this giant binary started on its journey one thousand years before the founding of the city of Rome, at about the time when the nomad Abraham commenced his wanderings, and after these thirty-four centuries, one-half the span of authentic history, reached our spectroscope, with the information outlined in the above article.

Victoria, B.C.,
May 1925.

REFERENCES

[1]Pub. D.A.O., II, No. 16
[2]Pub. D.A.O., I, No. 17
[3]Nature, *107*, p. 488, 1921
[4]Mt. W. Cont. *10*, p. 404
[5]Ibid, *10*, p. 399
[6]Pub. A.S.P., *32*, p. 307
[7]M.N., *77*, 16, 596; Ap. J., *48*, p. 205
[8]Ap. J., *48*, p. 211
[9]Pub. D.A.O., II, p. 329
[10]M.N., *77*, p. 605
[11]Mt. W. Cont., *10*, p. 398
[12]Ibid, *10*, p. 402
[13]Campbell, Stellar Motions, p. 263
[14]L.O.B., *XI*, p. 173, 1924
[15]Eddington, Stellar Movements, p. 167
[16]Pub. D.A.O., *II*, p. 327
[17]Ast. J., *832*, p. 129

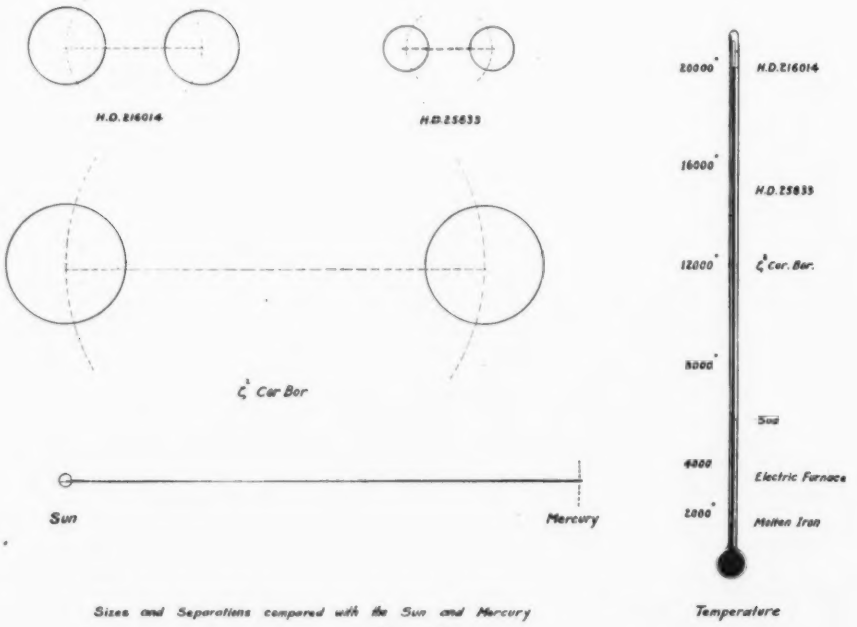

H.D. 216014
H.D. 25635
ζ¹ Cer Bor
Sun
Mercury
20000°
16000°
12000°
8000°
4000°
2000°
H.D. 216014
H.D. 25635
ζ¹ Cer. Bor.
Sun
Electric Furnace
Molten Iron
Sizes and Separations compared with the Sun and Mercury
Temperature

Figure II.

The Royal Astronomical Society of Canada

(OFFICERS FOR 1924—REVISED TO MARCH 1ST, 1924)

Honorary President—HON. G. H. FERGUSON, K.C., B.A., LL.D., Minister of Education for Ontario.
President—R. M. STEWART, M.A., Ottawa,
First Vice-President—WM. BRUCE, J.P., Hamilton.
Second Vice-President—A. F. HUNTER, M.A., Toronto.
General Secretary—F. T. STANFORD, Toronto.
General Treasurer—H. W. BARKER, Toronto.
Recorder—H. F. BALMER, B.A.
Librarian—PROF. C. A. CHANT.
Curator—ROBERT S. DUNCAN.

Council—MGR. C. P. CHOQUETTE, M.A., LIC.SCS., Montreal; R. E. DELURY, Ph.D., Ottawa; J. B. FRASER, M.D., Toronto; R. A. GRAY, B.A., Toronto; A. R. HASSARD, B.C.L., Toronto; J. H. HORNING, M.A., Toronto; PROF. JOHN MATHESON, M.A., Kingston; SIR JOSEPH POPE, K.C.M.G., Ottawa; JOHN SATTERLY, M.A., D.Sc., Toronto; DR. W. M. WUNDER, Toronto; and Past Presidents: JOHN A. PATERSON, M.A., K.C.; SIR FREDERIC STUPART, F.R.S.C.; A. T. DELURY, M.A.; LOUIS B. STEWART D.T.S.; ALBERT D. WATSON, M.D.; ALLAN F. MILLER; J. S. PLASKETT, B.A., D.Sc., F.R.S.; J. R. COLLINS; W. E. W. JACKSON, M.A.; and the Presiding Officer of each Centre as follows: R. J. MCDIARMID, Ph.D., Ottawa; REV. FATHER T. W. MORTON, B.Sc., Winnipeg; W. E. HARPER, M.A., Victoria, B.C.; JUSTICE E. E. HOWARD, Montreal; H. R. KINGSTON, M.A., Ph.D., London, Ont., and the Officers as above

OTTAWA CENTRE

President—R. J. MCDIARMID, Ph.D. *Vice-President*—C. R. COUTLEE, C.E.
Secretary—A. H. MILLER, M.A. *Treasurer*—W. S. MCCLENAHAN, B.A.

Council—T. L. TANTON, Ph.D.; E. A. HODGSON, M.A.; THOMAS DONOHER, and Past Presidents: R. M. STEWART, M.A.; F. A. MCDIARMID, M.A.; J. J. MCARTHUR, D.L.S., and R. E. DELURY, Ph.D.

MONTREAL CENTRE

Honorary President—MGR. C. P. CHOQUETTE, M.A., LIC.SCS.
President—HON. JUSTICE E. EDWIN HOWARD.
1st Vice-President—MR. H. E. S. ASBURY.
2nd Vice-President—PROF. A. H. S. GILLSON.
Secretary-Treasurer—MR. A. W. STRONG.
Recorder—REV. W. T. B. CROMBIE, M.A., B.D.
Assistant Recorder—MISS A. V. DOUGLAS.

Council—PROF. A. S. EVE, D.Sc., C.B.E.; MR. GEO. SAMPLE; MR. JULIAN C. SMITH; MR. E. W. PASK; MISS M. I. ELLICOTT.

LONDON CENTRE

President—H. R. KINGSTON, M.A., Ph.D.
Vice-President—MISS GRACE BLACKBURN.
Secretary-Treasurer—E. T. WHITE, B.A., D.Paed.

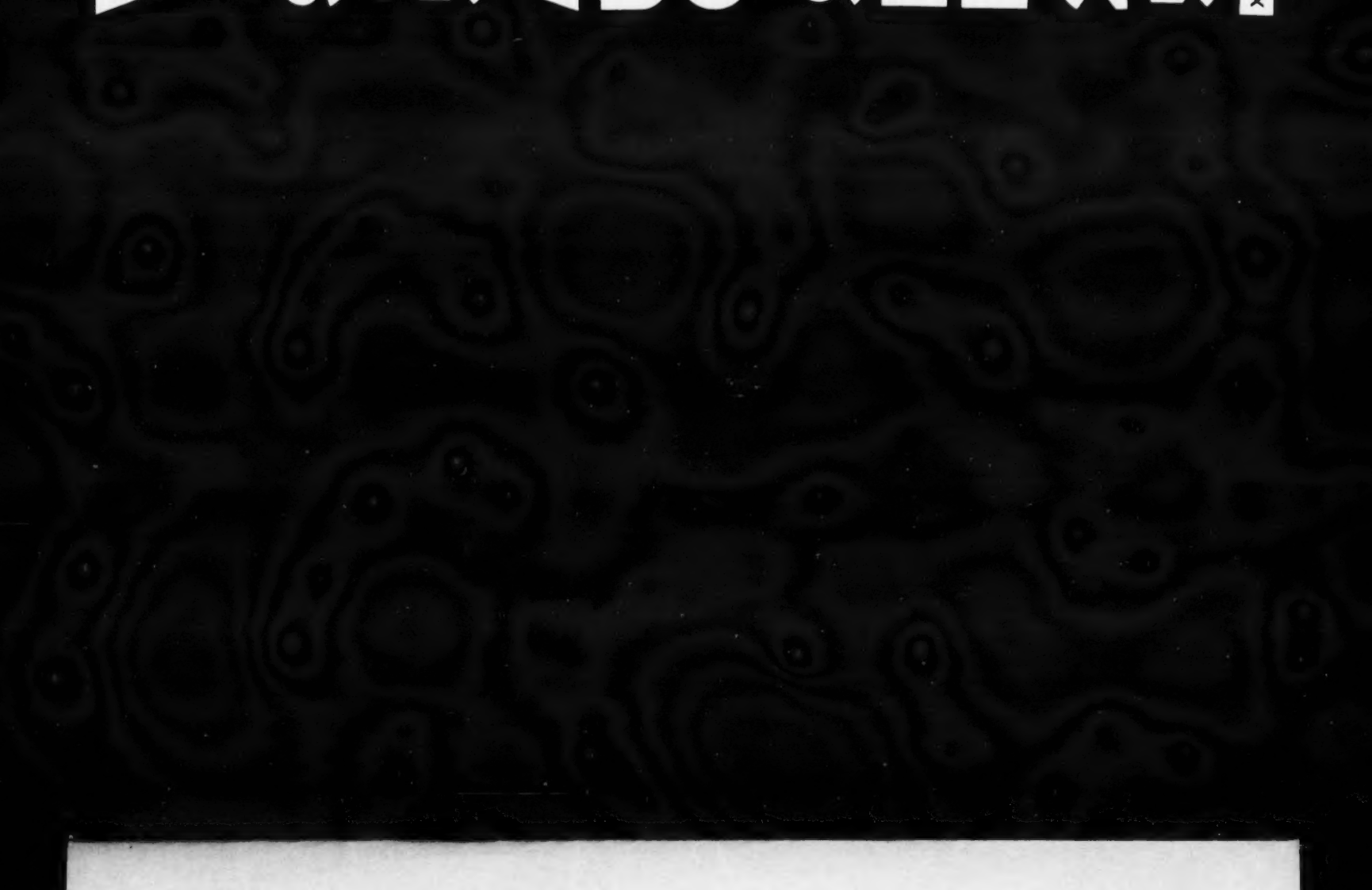
Council—REV. R. J. BOWEN, F.R.G.S.; MRS. S. R. MOORE; H. B. HUNTER; J. C. MIDDLETON; W. A. MCKENZIE.

WINNIPEG CENTRE

President—REV. T. W. MORTON, B.Sc.
Vice-President—MRS. E. L. TAYLOR.
Curator—DR. L. A. H. WARREN.
Secretary-Treasurer—MR. H. B. ALLAN.

Council—DR. N. B. MACLEAN; MRS. S. C. NORRIS; MR. D. P. MORSE, C.E.; DR. N. R. WILSON; MR. J. H. KOLB; MR. CECIL ROY.

VICTORIA CENTRE

Honorary President—DR. J. S. PLASKETT, F.R.S.
President—MR. J. DUFF.
Vice-President—MR. F. C. GREEN.
Treasurer—MR. J. P. HIBBEN.
Secretary—MR. F. MOORE.

Executive Committee—MESSRS. P. H. ELLIOTT; H. CAMERON; R. G. MILLER; W. H. CHRISTIE.
Auditor—MR. H. H. PLASKETT.